# CHANGE OF DIRECTION

## WHAT TESTS AND WHAT VARIABLES DO I NEED TO ASSESS AND HOW TO TARGET THEM IN REHAB

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INTRODUCTION

Change of direction maneuvers, particularly side-step cutting have been identified as a key mechanism of non-contact anterior cruciate ligament (ACL) injuries.[1-3] This is mainly due to the fact that the biomechanics associated with faster change of direction performance (e.g., greater lateral foot plant distance) are often in direct conflict with safer change of direction mechanics (i.e., reduced knee joint loading).[4-7] Athletes with ACL injury that are intending to return to compete in multidirectional sports commonly undergo ACL reconstruction.[8] According to previous research, physical and technical attributes (i.e., neuromuscular control, co-contraction, and rapid force production) are significantly impaired after ACL reconstruction.[9-13] It was reported that these deficits persist even at the time to return to sport, potentially with greater risk of re-injury.[9-13] As such, assessing the restoration of knee function and lower limb mechanics during change of direction tasks is key to inform rehabilitation status and safe return to sport.

The objective of this piece of this article is 2-fold:

1. to examine the change of direction tests that have been used in athletes with ACL reconstruction and their utility to identify residual deficits and risk factors associated with secondary ACL injury;
2. to outline the criteria and the main activities/exercises adopted during rehabilitation to restore change of direction mechanics while improving change of direction performance.

WHAT IS CHANGE OF DIRECTION?

Change of direction and agility are often used interchangeably; however, it is important to distinguish between them. Agility involves rapid whole-body movements with change of speed or direction in response to a stimulus”[14]. On the other hand, change of direction ability refers to planned movements without reacting to a stimulus and serves as the foundation for agility performance (Figure 1)[15-18].

CHANGE OF DIRECTION ASSESSMENT

Assessing knee function during change of direction tasks following ACL reconstruction is essential to: tailor rehab training programs, identify risk factors for secondary ACL injury, and to inform return-to-sport decision making[20]. Existing literature has used a combination of field and lab-based tests to assess knee function following ACL reconstruction and to determine readiness to return to sport[21]. The most commonly used field-based assessments include the shuttle run, co-contraction, carioca, T test, and modified T test[22-28], while 45°[12,13,29] and 90° sidestep cutting[10,11] have been adopted within a laboratory setting.

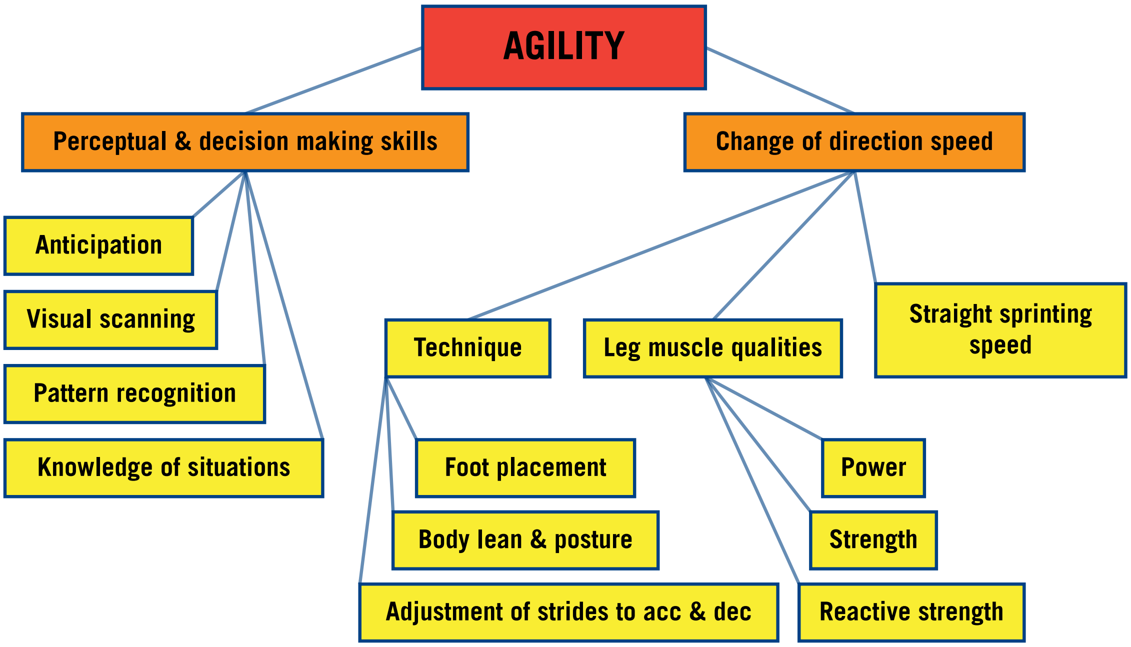


**Figure 1:** Deterministic model of agility performance (Adapted from Young & Farrow, 2006)[19].

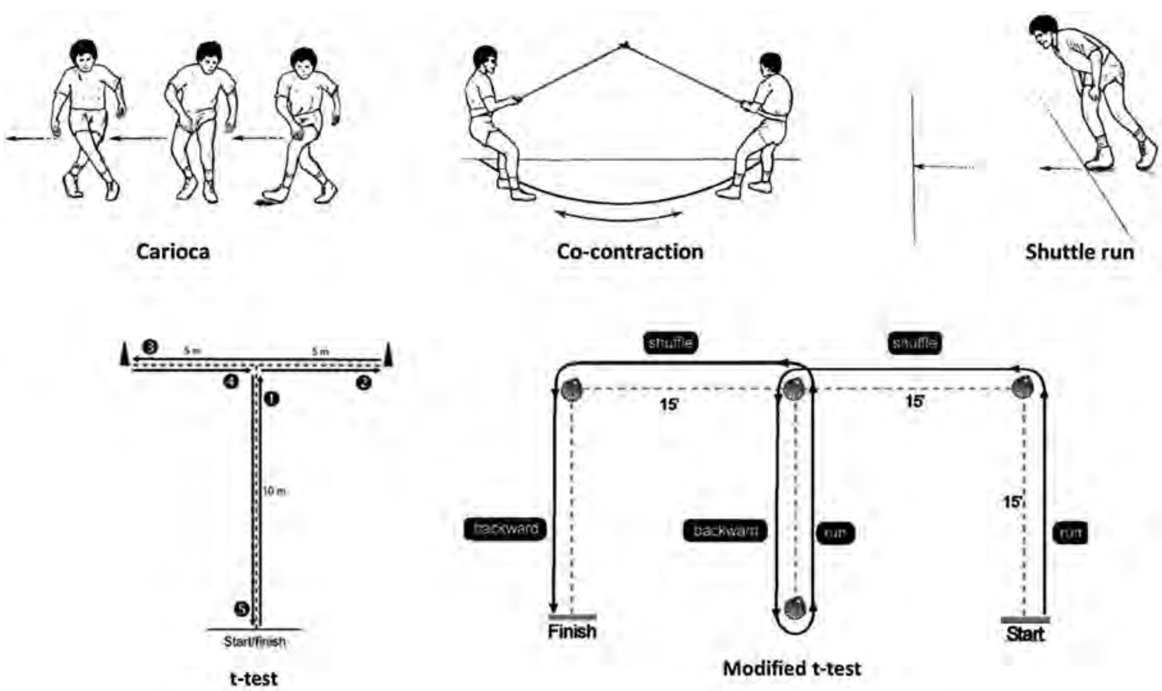


**Figure 2:** Field-based change of direction tests that have been adopted to assess athletes following ACL reconstruction (Adapted from Marques et al[21]).

FIELD-BASED ASSESSMENTS

Field-based assessments (co-contraction, carioca, shuttle run, T test, modified T test) are practically viable; however, they rely on completion time (i.e., performance) as the primary metric to evaluate athletes' readiness (Figure 2). Despite the importance of the performance component, using time as the only metric to evaluate change of direction ability is not sufficient to identify important qualitative information (e.g., trunk position, foot placement, center of mass height, knee angles, arm actions and visual focus) presented by an athlete while executing the change of direction movement[13].

When time (i.e., performance) is the only metric available to measure change of direction ability, cut-off 'pass scores' should represent high performance values required for elite athletes returning to professional sport[21]. Also, wherever possible, general cut-off 'pass scores' should be replaced by individual pre-injury performance data to make decisions relative to the individual (considering differences in strength, speed, change of direction ability, etc.). Applying the same absolute score to all athletes could be too conservative/demanding for faster and slower athletes, respectively, highlighting the importance of collecting base-line data on all players as part of a regular screening/monitoring program[21].

It is also important to critically appraise the use of these field-based assessments as change of direction maneuvers. Specifically, the movement patterns displayed by the co-contraction, carioca, T test, and modified T testing protocols bears little to no resemblance to how an athlete would move in a sport-specific setting, particularly during cutting and turning maneuvers during competition. Change of direction at high speed requires an individual to rapidly decelerate to change their momentum, and then re-direct their body towards the intended direction of travel prior to re-accelerating with minimal time loss[14].

From these protocols, the shuttle run test most closely resembles the components of a change of direction assessment. It should be noted however that during this type of task (i.e., 180° turn), most of the time (70%) is influenced by linear speed with a substantially lower proportion (30%) spent during the turning phase[30], and this may mask the actual change of direction performance of an athlete[17]. In addition, evaluating the entry and exit velocity may be of interest to more clearly elucidate how the direction change is performed, further removing the effect of confounding factors such as linear speed[17].

LAB-BASED ASSESSMENTS

Lab-based studies have identified residual deficits and altered movement strategies at the time of return to sports, and this might be related to risk of re-injury[10-13,29]. Table 1 displays a summary of the main findings reported by lab-based studies that have examined lower extremity biomechanics during change of direction tasks following ACL reconstruction.

Figure 3 displays the common residual deficits identified on the involved limb for athletes with ACL reconstruction during both planned and unplanned change of direction tasks performed at 45° and 90°. For instance, variables associated with ACL injury mechanism, including, knee abduction moment, knee flexion and internal rotation angles remained present

**Table 1**

| *Study* | *Subjects* | *Period of assessment* | *Aim of the study* | *Testing protocol/ Measurement* | *Main findings* |
|---|---|---|---|---|---|
| *Stearns and Pollard[13]* | *Female soccer players<br><br>ACL-R (n = 12)<br><br>Healthy control (n=12)* | *12-months after surgery* | *Comparison ACL-R vs. Healthy Controls* | *45° sidestep cutting; 3D motion analysis system and floor embedded force platform* | *The ACL-R group exhibited increased knee joint loading compared with healthy matched control, suggesting that frontal plane knee function is not fully restored at the time to RTS* |
| *Pollard et al[12]* | *Female soccer players<br><br>ACL-R (n = 10)<br><br>Healthy control (n=10)* | *12-months after surgery* | *Comparison ACL-R vs. Healthy Controls* | *45° sidestep cutting; 3D motion analysis system and floor embedded force platform* | *The ACL-R players exhibited increased lower extremity variability during the cutting task as compared with the healthy counterparts, suggesting altered neuromuscular control as a result of ACL-R* |
| *King et al[10]* | *Male athletes (n = 156) from multidirectional sports with ACL-R;* | *9-months<br><br>after surgery* | *Comparison Involved vs.<br><br>Uninvolved limb and<br><br>between Planned vs. Unplanned COD* | *90° cutting; 3D motion analysis system and floor embedded<br><br>force platform and light timing system* | *No differences in COD performance were found between limbs and conditions. However, higher biomechanical deficits were observed on the involved limb and during unplanned COD in variables associated with ACL injury mechanism, suggesting that performance-based criteria may not be the most sensitive variable to be used to discharge athletes back to sports participation* |
| *King et al[11]* | *Male athletes ACL-R (n = 156)<br><br>Healthy control (n=62)* | *9-months<br><br>after surgery* | *Comparison ACL-R vs. Healthy Controls* | *90° cutting; 3D motion analysis system and floor embedded<br><br>force platform and light timing system* | *The ACL-R group was more asymmetrical compared to healthy counterparts, suggesting incomplete restoration of normal movement 9 months after ACL-R* |
| *Clark et al[9]* | *Male athletes ACL-R (n = 10)* | *> 9-months after surgery* | *Comparison Involved vs. Uninvolved limb* | *90° cutting; 3D motion analysis system* | *Higher knee joint angle impairment on the involved limb* |

**Table 1:** Lab-based studies have examined lower extremity biomechanics during COD tasks following ACL-R.

even at the time to return to sport (i.e. 9-months post-surgery).

FIELD VS LAB-BASED ASSESSMENTS

Despite the efficacy of lab-based assessments in identifying residual biomechanical deficits during change of direction tasks following ACL reconstruction, this approach is not practically viable for sports teams. On the other hand, field-based functional assessments have been proposed as a more realistic approach. However, research indicates that change of direction time is not sensitive enough to identify deficits in knee function when biomechanical alterations exist[11]. Table 2 displays the main advantages and disadvantages between field and lab-based approaches to assess knee function following ACL reconstruction.

*Change of direction vs Agility assessment*

Rarely in match play do rapid direction changes take place in optimal conditions where athletes have time to select the appropriate movement strategy due to the reactive nature of invasion sports. A systematic review and meta-analysis of sidestepping cutting[31] reported that several biomechanical variables describing sidestepping technique were significantly different when reacting to a stimulus, when compared to a pre-planned change of direction task in healthy team sport athletes. As such, differences in biomechanical variables between limbs during change of direction tasks may alter depending on whether they are planned or unplanned maneuvers. The presence of common differences between limbs in both planned and unplanned change of direction tests may influence the practitioner's decision as to whether an athlete is ready to return to play and indicate if either or both tests are suitable for inclusion in return to sports testing[10].

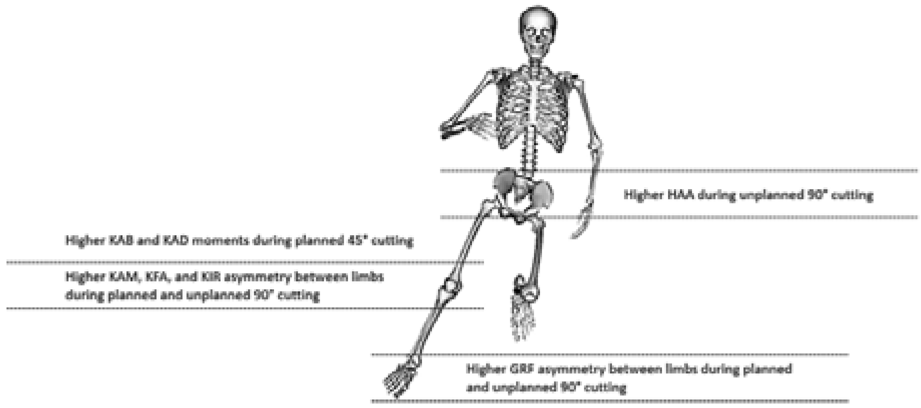


**Figure 3:** Illustration of a change of direction task and common deficits identified on the involved limb for athletes with ACL reconstruction at the hip, knee and foot during both conditions planned and unplanned reported by lab-based studies[9-13]. Legend: ACLR=anterior ligament reconstruction; GRF=ground reaction force; HAA=hip abduction angles; KAB=knee abduction; KAD=knee adduction; KAM=knee abduction moments; KFA=knee flexion angles; KIR=knee internal rotation angles.

**TABLE 2**

| *Assessment approach* | *Field-based* | *Lab-based* |
|---|---|---|
| *Advantages* | • *Requires no expensive equipment.*<br>• *No time consuming and easy applicability.*<br>• *Assess higher number of subjects within one testing session.* | • *Reliable data.*<br>• *Assess mechanics of the change of direction task (Kinetics and kinematics) and the strategy adopted by the athletes.*<br>• *Valuable diagnostic of the knee function (between limb deficits).* |
| *Disadvantages* | • *Lack of reliability.*<br>• *Does not resemble change of direction maneuvers performed during sport-specific setting.*<br>• *Relies on performance metric (completion time) only.*<br>• *Not able to identify the strategy adopted by the athletes during the change of direction task.*<br>• *Not able to diagnostic knee function during the change of direction task.* | • *Requires expensive equipment.*<br>• *Assess low number of subjects during each testing session.*<br>• *Time consuming for data analysis.*<br>• *Lacks ecological validity.*<br>• *Not practically viable for team sports.* |

**Table 2:** Advantages and disadvantages of field and lab-based change of direction testing.

Planned change of directions tests (i.e., carioca, co contraction, shuttle run, T test, modified T test) without temporal constraints may afford sufficient time for the adoption of a 'safer' and more optimal movement execution. For example, using the support foot placement strategy prior to initial contact of the push-off foot to initiate the direction change may allow athletes to lowering the mechanical stress on the knee[32]. While research advocates that change of direction research findings cannot automatically be extrapolated to agility in invasion sports[33], this approach seems to be safer to assess athletes under the rehabilitation process, since it may reduce the risk of ACL injury. In addition, it also allows athletes with ACL reconstruction to develop mechanical cutting ability, which can be considered an important attribute to be developed first, particularly from a motor skill learning perspective. Adopting this strategy prior to incorporating unanticipated stimulus within practice drills may help athletes to be highly prepared for the chaotic demands of multidirectional sports[34].

Change of direction tasks can be performed in response to either generic (e.g., light-based system) or quasi-realistic (e.g., react against 1 or 2 defenders' scenarios in a 3-dimension video projection) external stimuli. The generic unplanned stimuli (i.e., reacting to a light system) utilized during the change of direction test does not provide an ecologically valid stimulus. High performance athletes will use their "game knowledge" and anticipate situations based on phase of play sequences and then react to the movement cues displayed by their opponents[35]. Therefore, using tests that involve generic cues (such as light stimulus) are likely to be limited in their ability to assess transferrable sport specific abilities of athletes which require integration of perception-action coupling, and decision-making to effectively execute a change of direction task. This lack of realistic scenario may limit our ability to fully understand the impact of a true unplanned 'agility' action on ACL injury risk.

## THE IMPORTANCE OF DECELERATION

Rapid deceleration (stop type activities) might be a risk for ACL injury due to an increase in anterior tibial shear force and anterior tibial translation[36]. Higher cutting angles (i.e., ≥60°) require greater reductions in velocity to change the athlete's momentum[37,38]. Greater braking forces during the penultimate foot contact ensure that athletes can maintain a higher entry velocity (as they can brake later) which results in faster change of direction speed and reduce the knee joint loading (i.e., ground reaction force) on the turning limb during the plant step[39]. This has important implications as non-contact ACL injuries often occur on the planted limb during a sudden deceleration prior to a change in direction[40]. As such, deceleration plays a key role in change of direction mechanics. Thus, it may be prudent to examine kinematics and loading characteristics during deceleration as an isolated construct (without the change of direction component), particularly at an earlier stage of on pitch / court rehabilitation to examine an individual's ability to effectively apply braking forces as a pre-cursor to change of direction.

## REHABILITATION OF CHANGE OF DIRECTION MECHANICS

***Criteria to start change of direction***

From the section above you can see the various components that comprise change of direction testing and agility assessment and the common deficits identified after ACLR. We look to develop change of direction mechanics well in advance of change of direction drills and then progress through to sports specific agility in our on-field rehabilitation. At Aspetar, the criteria for sports specific on-field rehabilitation are:

- At least 4 months post op for ACLR and 5 months post op for ACL Revision and adolescents below 17 years old. If earlier, surgeon's approval required.
- Symmetrical Extension / Flexion >130°
- No pain or increased swelling with activity
- Isokinetic testing quads Limb symmetry index ≥ 75 % for quads and hamstrings
- Hip Abduction and Adduction strength > 90% Limb symmetry index
- Single Leg Drop Jump and counter-movement jump (height and RSI)>75% LSI
- Completed the Running Curriculum (6X200m at 16km/h, 12km/h for court sports/recreational)
- Appropriate movement quality during functional movements (single leg Squat to 90 degrees knee flexion, single leg Landing in all 3 planes, symmetrical lateral push off and cross over)

As highlighted above and in Figure 1 you will see the foundation of motor control, strength, explosiveness, reactive strength and running are the building blocks for on-field and higher intensity change of direction drills. While these qualities are being developed we target 4 movement streams to address key biomechanical components specific to change of direction:

1. Footwork/Co-ordination
2. Ability to decelerate/absorb
3. Ability to push off/propel
4. Ability to combine absorption and propulsion in multiple planes – side stepping/lateral rebounds

Some of these components are developed in advance of transitioning to on-field rehabilitation (landing, footwork and push off mechanics) and others are further progressed in parallel to the on-field process.

Key to influencing biomechanical changes throughout this period is considering change of direction as a motor skill and creating drills and an environment that constrain the common deficits identified during testing while allowing

**TABLE 3**

| *Footwork* | *Deceleration* | *Push Off* | *Sidestep/Rebound* |
|---|---|---|---|
| *Backward Shuffle* | *SL Landing* | *Banded Lunge to Bench* | *Lateral Rebound off Step* |
| *Backward Shuffle with Rotation* | *Forward Hop* | *Sled Acceleration* | *Cone Hop and Lateral Rebound* |
| *Forward/Backward shuffle transition on command* | *Backward Hop* | *Lateral Push off* | *Lateral Banded Shuffle* |
| | *Lateral Hop* | *Lateral Cross over* | *180 Degree Medball Throw* |
| | *Rotation Hop* | | |
| | *Run to Decel Step Planned* | | |
| | *Run to Decel Step Reactive* | | |

**Table 3:** Change of Direction Mechanics Drills.

the body to self-organize and the desired motor strategies to emerge which can then be challenged in response to sports specific stimuli on-field (agility). Our goal in rehabilitation is to improve/redevelop the athletes vocabulary so that they can express it unconsciously in higher demand activities later in rehabilitation and as they transition back to team training.

A sample of some change of direction drills that can be used are presented in Table 3 and some of them are outlined in Table 3 and some of them are outlined in more detail in the section below. These sessions would be carried out 2-3 times per week, ideally prior to a running session. While each exercise is commonly 4-5 repetitions for 3-4 sets, the focus is on the quality of the efforts rather than the volume of training to optimize motor learning.

*Footwork*

The goal of footwork drills is to encourage the athlete to start to co-ordinate their foot movement to facilitate changing direction in multiple planes as required when transitioning to more open or chaotic drills later in the rehabilitation process.

*Backward shuffle with rotation (Figure 4)*

The athlete is asked to shuffle backwards while switching (rotating) stance.

Key coaching points:

- Stay low with shuffle (no up and down movement)

Progressions:

- Introducing constraints (Hands forward looking through "camera")
- Multidirectional (front/back and side)
- Unplanned (Patient reacts to an external stimulus to switch or change direction of movement).

*Deceleration*

Key to the commencement of deceleration drills is the ability to hop and land in multiple planes. The amount of deceleration needed during change of direction is directly influenced by the angle change during the redirection step[41]. Therefore the ability to tolerate deceleration at higher intensities needs to be developed prior to progressing to more challenges angles.

0-45°

- Little to no braking required.
- Approach speed mostly maintained.
- Crossover cut/step mostly implemented.

45-60°

- Moderate braking required (mostly in final step).
- Approach speed moderately altered.
- Sidestep mostly implemented.

60-180°

- Substantial braking needed in the approach and final step.
- Approach speed substantially altered.
- Combination of techniques used.

*Lateral Hop*

The athlete is asked to hop laterally and to stick the landing

Key coaching points:

- Land "quick" and "quiet" (to maximise speed of recruitment and reduce rigid/stiff landing strategy)

Progression:

- Stick overhead to constrain trunk
- Greater hop distance
- Bungee pull to increase the lateral momentum into the landing
- Aquabag to provide perturbation to the landing

*Deceleration step (Figure 5)*

The athlete is asked to run and stop using the involved leg at a defined stopping point

Key coaching points:

- Speed to decelerate to full stop to be emphasised
- Positive trunk and shin angle while lowering centre of mass – do not fall forward

Progression:

- Distance from start position to end point increased (speed increase).
- Reactive - no specific end point. Patient reacts to and external stimulus to stop.

*Push Off:*

The three different strategies are targeted (acceleration forward, lateral push off and lateral crossover) which can later combine the footwork development to adjust one's feet while in motion in sports specific agility drills[34].

**Figure 4**

**Figure 5**

**Figure 6**

**Figure 7**

**Figure 8**

**Figure 9**

**Figure 10**

*Acceleration forward – Lunge to Bench (Figure 6)*
The athlete is asked to push off onto bench as quickly as possible.

Key coaching points:
- Explosive action
- Triple extension end position for each repetition.
- Movement forwards and not upwards.

Progressions:
- Increasing resistance
- Introducing perturbations (aqua bag)

*Crossover step (Figure 7)*
The athlete is asked to step across their body and back into the start position.

Key coaching points:
- Stay low (no up and down movement- lateral only)
- No push off with leg crossing over.

Progressions:
- Increasing resistance
- Introducing constraints (stick overhead- to prevent trunk lean/rotation)

*Lateral push off (Figure 8)*
The athlete is asked to push away/off as far as possible in a single step.

Key coaching points:
- Stay low (no up and down movement- lateral only)
- No pull with leg stepping out (push only).

Progressions:
- Increasing band resistance
- Introducing constraints (stick overhead- to prevent trunk lean/rotation)

*Sidestep/Rebound*
Lateral rebound off step (Figure 9)
The athlete is asked to fall/step off laterally to desired point, push off and return to the starting position as quickly as possible.

Key coaching points:
- As return to starting position as quickly as possible.
- Centre of mass to move (not just a side step).

Progressions:
- Introducing constraints (stick overhead- to prevent trunk lean/rotation)
- Introducing perturbations (aqua bag)

*Lateral Cone Hop (Figure 10)*
The athlete is asked to hop over the first cone and push off laterally to the next cone as quickly as possible.

Key coaching points:
- Stay low with lateral movement (no up and down movement- lateral only)

Progressions:
- Introducing constraints (stick overhead- to prevent trunk lean/rotation)
- Introducing perturbations (aqua bag)
- Increase intensity – higher cones/ hurdles or wider distance between cones

The type of exercises above expose and target the common biomechanical deficits seen after ACLR including long ground contact time, trunk sway, knee valgus and reduced knee flexion. Targeting these movements and deficits in advance of and throughout the return to on-field sports specific training and more chaotic and advanced agility drills will greatly improve the speed of recovery, athletic performance and injury risk of the athlete.

*References*
*Available at www.aspetar.com/journal*

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